CLAIMS

What is claimed is:

1. A fuel processor for generating a H_2 rich gas from a fuel, comprising:

(a) an inlet projecting through an exterior housing of the fuel processor attached to a steam line, an O_2 rich gas line, and a fuel line;

(b) an inner reforming zone comprising a sidewall, a first end connected to the inlet, a partial oxidation catalyst and a steam reforming catalyst or a combined partial oxidation and steam reforming catalyst, and a second end;

(c) an outer reforming zone comprising the sidewall of the inner reforming zone, an outer sidewall, a first end connected to the second end of the inner reforming zone, and a second end;

(d) a cooling zone comprising a first end connected to the second end of the outer reforming zone and a second end;

(e) a sulfur removal zone comprising a sulfur removal agent, a first end connected to the second end of the cooling zone, and a second end; and

(f) a water-gas-shift zone comprising a catalyst that catalyzes the conversion of carbon monoxide and water to carbon dioxide and H_2, a first end connected to the second end of the sulfur removal zone, and a second end connected to an outlet of the fuel processor.

2. The fuel processor of claim 1, wherein the cooling zone further comprises an injection tube that allows water to be directly injected into the cooling zone.

3. The fuel processor of claim 1, wherein the outer reforming zone further comprises a partial oxidation catalyst and a steam reforming catalyst or a combined partial oxidation and steam reforming catalyst.

4. The fuel processor of claim 1, wherein the inner reforming zone comprises a combined partial oxidation and steam reforming catalyst comprising a transition metal and an oxide-ion conducting portion, further wherein the transition metal is selected from the group consisting of platinum, palladium, ruthenium, rhodium, iridium, iron, cobalt, nickel, copper, silver, gold, and combinations thereof, and the oxide-ion conducting portion is selected from the group consisting of ceramic oxides crystallizing in the fluorite structure, $LaGaO_3$, and mixtures thereof.

5. The fuel processor of claim 4, wherein the combined partial oxidation and steam reforming catalyst is platinum on gadolinium doped ceria.

6. The fuel processor of claim 1, wherein the sidewall of the inner reforming zone and the outer sidewall of the outer reforming zone are formed from stainless steel.

7. The fuel processor of claim 1, further comprising a steam heating zone disposed between at least a portion of the outer reforming zone and at least a portion of the water-gas-shift zone.

8. The fuel processor of claim 1, further comprising an air heating zone disposed between at least a portion of the water-gas shift zone and the exterior housing of the fuel processor.

9. The fuel processor of claim 1, wherein the sulfur-removal agent comprises zinc oxide.

10. The fuel processor of claim 1, wherein the catalyst in the water-gas-shift zone comprises a noble metal on ceria, wherein the noble metal is selected from the group consisting of ruthenium, rhodium, palladium, platinum, and combinations thereof.

11. A fuel processor for generating a H_2 rich gas from a fuel, comprising:

(a) an inlet projecting through an exterior housing of the fuel processor into a mixing zone, the inlet attached to a steam line and a fuel line;

(b) an inner reforming zone comprising a sidewall, a first end connected to the inlet, and a second end;

(c) an inner tube attached to an O_2 rich gas line and at least partially surrounded by the inner reforming zone;

(d) an outer reforming zone comprising the sidewall of the inner reforming zone, an outer sidewall, a first end connected to the second end of the inner reforming zone, and a second end;

(e) a cooling zone comprising a first end connected to the second end of the outer reforming zone and a second end;

(f) a sulfur removal zone comprising a first end connected to the second end of the cooling zone, and a second end; and

(g) a water-gas-shift zone comprising a first end connected to the second end of the sulfur removal zone, and a second end connected to an outlet of the fuel processor.

12. The fuel processor of claim 11, wherein the water-gas-shift zone further comprises a first water-gas-shift zone and a separate second water-gas-shift zone, further wherein the first water-gas-shift zone comprises a first end connected to the second end of the sulfur removal zone and a second end, and further wherein the second water-gas-shift zone comprises a first end connected to the second end of the first water-gas-shift zone and a second end connected to the outlet of the fuel processor.

13. The fuel processor of claim 12, further comprising a cooling tube having an inlet and an outlet and extending through the second water-gas-shift zone.

14. The fuel processor of claim 11, wherein the inner tube extends into the mixing zone.

15. The fuel processor of claim 11, further comprising a steam inlet extending through the exterior housing of the fuel processor and connected to a pipe that extends through the fuel processor to a steam outlet, the steam outlet connected to a steam line that is connected to the inlet projecting through the exterior housing of the fuel processor into the mixing zone.

16. The fuel processor of claim 11, further comprising a fuel inlet connected to a fuel line that runs through the fuel processor or around the exterior housing of the fuel processor to a fuel outlet, wherein the fuel outlet is connected to a fuel line that is connected to the inlet projecting through the exterior housing of the fuel processor into the mixing zone.

17. The fuel processor of claim 11, wherein the cooling zone comprises a coiled coolant tube that extends through the cooling zone.

18. The fuel processor of claim 11, wherein the inner reforming zone comprises a partial oxidation catalyst and a steam reforming catalyst or a combined partial oxidation and steam reforming catalyst.

19. The fuel processor of claim 18, wherein the inner reforming zone comprises a combined partial oxidation and steam reforming catalyst, the combined partial oxidation and steam reforming catalyst comprising a transition metal and an oxide-ion conducting portion, wherein the transition metal is selected from the group consisting of platinum, palladium, ruthenium, rhodium, iridium, iron, cobalt, nickel, copper, silver, gold, and combinations thereof, and the oxide-ion conducting portion is selected from the group consisting of ceramic oxides crystallizing in the fluorite structure, $LaGaO_3$, and mixtures thereof.

20. The fuel processor of claim 19, wherein the combined partial oxidation and steam reforming catalyst comprises platinum on gadolinium doped ceria.

21. The fuel processor of claim 11, wherein the sidewall of the inner reforming zone and the outer sidewall of the outer reforming zone are formed of stainless steel.